DISTRIBUTION OF MICROSPORE TYPES IN NEW SOUTH WALES PERMIAN COALFIELDS.

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(Five Text-figures.)

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Introduction.

In a recent publication (Dulhunty, 1945), the author described the principal microspore-types found in New South Wales Permian coal seams. A tabular system of type-numbering was suggested, and spore types were illustrated by photomicrographs and line-drawings. For details of different types referred to in the present paper, and the method of type-numbering used, reference should be made to the above publication. For the convenience of readers, however, an abridged key to the spore-types is given in Table 1.

Table 1.
Abridged Key to Spore-Types.

Examples of type-numbering: P2A, P29B, P34C, P40D.

Letter P preceding type-number indicates Permian type.
Letter A, B, C or D following type-number indicates variations in size or minor details of spores belonging to the same general type.
Type-numbers (2, 29, 34, 40 in above examples) refer to body-shape, tetrad scar and ornamentation, as follows:

1 Angular tetrahedral; trilete; psilate.
2 Sub-ang. tetrahedral; trilete; psilate.
3 Ellipsoidal; monolete; psilate.
4 Spheroidal; trilete; psilate.
5 Spheroidal; monolete; psilate.
6 Ang. tetrahedral; trilete; granulate.
7 Sub-ang. tetrahedral; trilete; granulate.
8 Ellipsoidal; monolete; granulate.
9 Spheroidal; trilete; granulate.
10 Spheroidal; monolete; granulate.
13 Ellipsoidal; monolete; reticulate.
14 Spheroidal; trilete; reticulate.
15 Spheroidal; monolete; reticulate.
16 Ang. tetrahedral; trilete; echinate.
17 Sub-ang. tetrahedral; trilete; echinate.
18 Ellipsoidal; monolete; echinate.
19 Spheroidal; trilete; echinate.
20 Spheroidal; monolete; echinate.
21 Ang. tetrahedral; trilete; striate.
23 Ellipsoidal; monolete; striate.
26 Ang. tetrahedral; trilete; verrucate.
28 Ellipsoidal; monolete; verrucate.
29 Spheroidal; trilete; verrucate.
30 Spheroidal; monolete; verrucate.
32 Sub-ang. tetrahedral; trilete; monowinged.
33 Ellipsoidal; monolete; monowinged.
34 Spheroidal; trilete; monowinged.
35 Spheroidal; monolete; monowinged.
38 Ellipsoidal; monolete; biwinged.
40 Spheroidal; monolete; biwinged.

This paper deals with stratigraphical distribution of microspores in different coal measures, and palaeogeographical distribution in the principal coalfields, as well as variations in relative abundance and diversity of types. Distribution is first considered from the viewpoint of individual types, and then in terms of groups of morphologically-related types and groups of types possessing similar forms of ornamentation. No attempt is made to discuss continuity of assemblages on specific coal-bearing horizons or stratigraphical variation between individual seams, as insufficient data are at present available.

The work was carried out as a preliminary survey of different aspects of microspore distribution, with the object of revealing promising fields in which subsequent research may provide results of value in palaeobotany or stratigraphy.

Material Examined.

Spore-counts were carried out in concentrates prepared from a series of forty-seven representative samples taken from coal seams in different coal measures and coalfields of the main Permian basin in central eastern New South Wales. The geographical distribution of samples selected for examination, and the arbitrary subdivision of the Permian coal-province into coalfields adopted for the present purpose, are illustrated in Fig. 1.

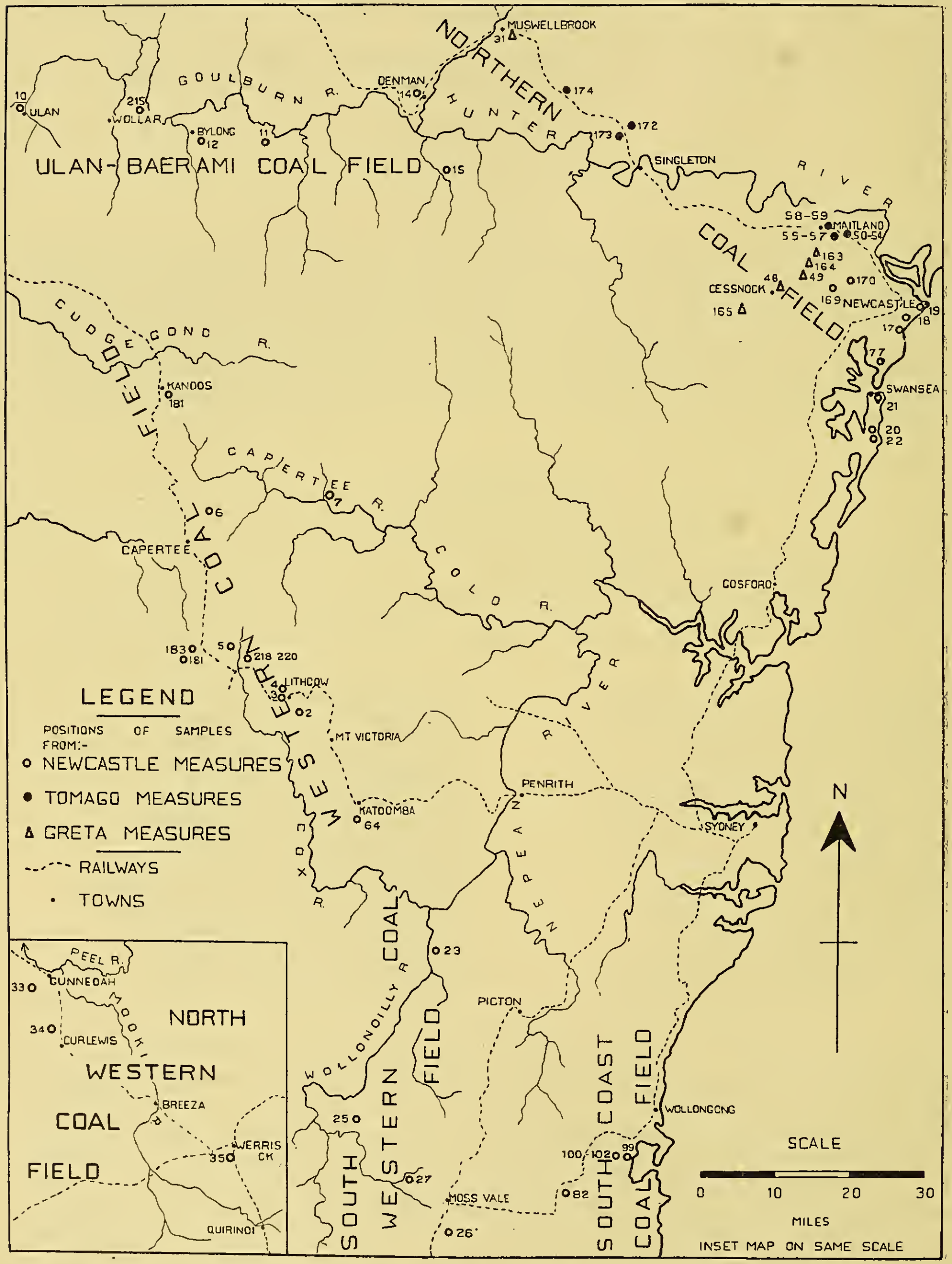

Fig. 1.—Central eastern New South Wales, showing Permian Coalfields and positions of coal samples.

The stratigraphical subdivision of Permian strata into coal measures (David, 1932; Raggatt, 1938; Jones, 1939) is shown in Table 2.

Table 2.

Stratigraphical Subdivision of Permian Strata in New South Wales.

Permian.	Upper Coal Measures.	Newcastle Stage.
		Tomago Stage.
	Upper Marine.	
	Lower or Greta Coal Measures.	
	Lower Marine.	

The Tomago and Newcastle Stages of the Upper Coal Measures are referred to, for convenience, as the Tomago and Newcastle Measures, it being understood that they are actually stages of the one coal-measure series.

Details regarding samples collected for spore-counts are given in Table 3 which shows the number of samples collected from each seam, and the stratigraphical sequence of seams in the different coalfields and measures.

Material was collected from as many seams as possible in the principal area of Permian coal-measure deposition. Samples from outlying areas, where correlation with measures in the main basin was uncertain, or where conditions of sedimentation may have been specialized, were not included, as the objects of the work were to determine stratigraphical ranges of microspore-types in measures of known sequence, and to study general distribution resulting from normal variation of conditions from central to marginal environments of deposition in the main coal basin. It is hoped to deal with outlying areas, and examine the possibility of their correlation with the main basin, in a subsequent publication.

Well-preserved microspores were found to occur abundantly in all coal seams except those in the South Coast Coalfield, where it was difficult to obtain seam-samples with sufficient spores for satisfactory spore-counts. Concentrates were prepared from over twenty samples collected from all seams there, but only three of them had sufficient spores for reliable counts. These, as indicated in Table 2, were from No. 3 and No. 4 seams. This leaves the other five seams unrepresented, so that assemblages of types and groups for the South Coast Coalfield, illustrated in this paper, may not represent a true average for all seams.

In the majority of samples from this Coalfield, unidentifiable remains of spores are present as almost opaque material which will not take safranin stain; and fragments of translucent plant-tissue, showing cell structure, are rare and will not stain. In view of this and also that the coal is known to contain more carbon and yield more fixed carbon than other New South Wales coals, it is probable that rarity of identifiable spores is due to advanced metamorphism rather than absence of spores in the original coal-forming débris.

Treatment of Material and Method of Making Spore-Counts.

Coal samples representing full sections of seams were taken where outcrop material was sufficiently fresh, otherwise the full height of working faces was sampled in mines. Each sample was crushed, mixed and reduced to about 5 lb. weight of coal passing a sieve of $\frac{1}{16}''$ mesh.

Spore concentrates, prepared by oxidation and solution of the coal, were mounted for microscopical examination by the method already described (Dulhunty, 1945). Three mounts of each concentrate were examined, under a magnification of 200 diameters, by working across the slides in different directions, and counting spore-types to a total number of several hundred. The number belonging to each individual type was then expressed as a percentage of the total identified in each concentrate, and results were used for statistical studies.

TABLE 3.
Particulars of Samples used for Spore-Counts.

Serial Nos. of Samples.	Seam.	Coalfield.	Coal Measures.
7, 64, 4	Katoomba.	Western.	Newcastle Stage, Upper Coal Measures.
6	Dirty.	,,	,, ,, ,, ,, ,,
183, (218–220).. ..	Irondale.	,,	,, ,, ,, ,, ,,
2, 3, 5, 181	Lithgow.	,,	,, ,, ,, ,, ,,
15, 14, 22	Wallarah or Top.	Northern.	,, ,, ,, ,, ,,
20	Great Northern.	,,	,, ,, ,, ,, ,,
77	Fassifern.	,,	,, ,, ,, ,, ,,
21	Pilot.	,,	,, ,, ,, ,, ,,
17	Burwood.	,,	,, ,, ,, ,, ,,
18	Nobby's.	,,	,, ,, ,, ,, ,,
19	Dirty.	,,	,, ,, ,, ,, ,,
170	Young Wallsend.	,,	,, ,, ,, ,, ,,
169	Borehole.	,,	,, ,, ,, ,, ,,
34, 35, 33	Seams at Gunnedah, Curlewis, Werris Creek.	North-western.	,, ,, ,, ,, ,,
11	Top. (? Katoomba Horiz.)	Ulan-Baerami.	,, ,, ,, ,, ,,
12, 215	Seam below Top. (? Dirty Horizon.)	,, ,,	,, ,, ,, ,, ,,
10	Bottom. (? Lithgow Horizon.)	,, ,,	,, ,, ,, ,, ,,
99	No. 3 or Dirty.	South Coast.	,, ,, ,, ,, ,,
82, (100–102) ..	No. 4.	,, ,,	,, ,, ,, ,, ,,
23	No. 1 or Bulli.	South-western.	,, ,, ,, ,, ,,
25, 26, 27	No. 3 or Dirty.	,, ,,	,, ,, ,, ,, ,,
(58–59)	Big Ben or Tomago Thick.	Northern.	Tomago Stage, Upper Coal Measures.
(50–54), (55–57) ..	Rathluba.	,,	,, ,, ,, ,, ,,
174	Liddell.	,,	,, ,, ,, ,, ,,
172, 173	Rix Creek.	,,	,, ,, ,, ,, ,,
31, 48, 49, 164, 165, 163	Greta.	,,	Greta Coal Measures.

VARIATION IN DIVERSITY OF SPORE-TYPES.

This was investigated by expressing the number of different types identified in each sample as a percentage of the forty-eight types found in New South Wales Permian coals, and the average percentages of types present in coals from different measures and coalfields were then obtained. Average results (Table 4) are shown for Greta and Tomago Measures in the Northern Coalfield, and for the Newcastle Measures in all coalfields, as well as separate coalfields.

TABLE 4.
Table showing Diversity of Spore-Types in Different Measures and Coalfields.

Newcastle Measures (all coalfields)	62·0%
Tomago Measures (Northern Coalfield)	68·5%
Greta Measures (Northern Coalfield)	62·8%
Newcastle Measures:	
South Coast Coalfield	46·5%
South-western Coalfield	67·8%
Western Coalfield	64·8%
Ulan-Baerami Coalfield	66·7%
Northern Coalfield	67·3%
North-western Coalfield	59·1%

There is relatively little variation in the average percentages. Coals from Tomago Measures show a greater variety of types than those from Greta Measures or Newcastle Measures in all coalfields. Figures for Newcastle Measures in separate coalfields are reasonably constant, except for the South Coast Coalfield, where they are low. This may be due to the limited number of samples examined, or to destruction of some spore-types by metamorphism.

In general, no variation of special significance is revealed in diversity of types present in the different coals.

Relative Abundance of Spore-Types.

The average relative abundance of individual spore-types in coals from all measures and fields was determined by obtaining the average percentage for each type. The results were then illustrated graphically by arranging the spore-types in order of abundance from left to right, with vertical columns above the types proportional to their average percentages. The diagram obtained is shown in Fig. 2. It indicates that

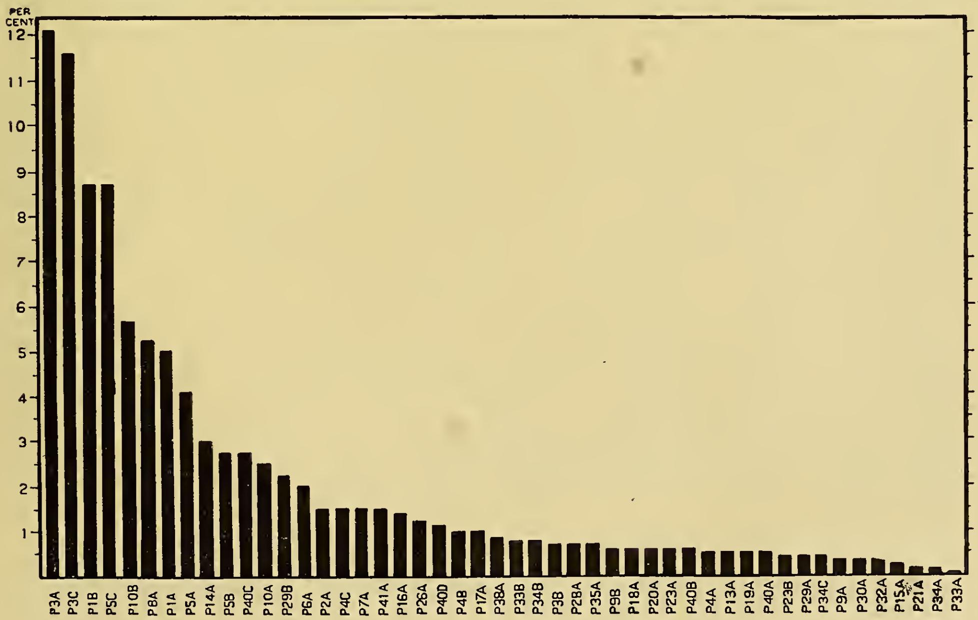

Fig. 2.—Relative abundance of microspore-types.

a small number of types predominates in abundance, and that the majority occur far less frequently.

The four most abundant spores are psilate: the ellipsoidal-monolete types P3A and P3C, amounting to 12·1 and 11·6 per cent. respectively, and the tetrahedral-trilete type P1B and the spheroidal-monolete type P5C each representing 8·7 per cent. These are followed by the two granulate types P10B and P8A, between 5 and 6 per cent.: both are monolete and differ only in their spheroidal and ellipsoidal shapes, respectively. Next come the small psilate types P1A, trilete, and P5A, monolete, between 4 and 5 per cent. The most abundant spore-types are all simple forms, and include the smallest of the Permian types recorded. Of the remaining forty types, six have averages between 2 and 3 per cent., nine between 1 and 2 per cent., and twenty-five less than 1 per cent.

Palaeogeographical Distribution of Spore-Types in the Newcastle Measures.

Study of palaeogeographical distribution was confined to variations in average relative abundance, and presence or absence of spore-types in the Newcastle Measures throughout the different coalfields. Greta and Tomago measures were not included, as typical outcrops occur only in the Northern Coalfield, and insufficient data are yet available for the study of palaeogeographical variations within that coalfield.

In each spore-count on coals from the Newcastle Measures, numbers of spores belonging to different types were expressed as percentages of the total number identified. The average percentage for each type was then obtained in all samples from each of the coalfields. Results for average relative abundance of each type thus obtained are given in Table 5 under the heading "Palaeogeographical Distribution". The absence of a spore-type in all samples from any particular coalfield is indicated by the letter A.

Table 5 shows considerable variation in relative abundance of spore-types throughout the different coalfields. This is most marked in the less common types, P16A, P18A, P33B and P40D, which are from four to six times more numerous in some fields than others. The more common types, P3C, P3A, P1A and P8A, show much less variation.

In some cases there is evidenee of progressive variation in relative abundance either from north to south or from marginal to central facies of coal-measure deposition. In the Newcastle Measures, types P1B and P33B are most numerous in southern districts, become less abundant in the Ulan-Baerami and Northern Coalfields, and reach a minimum in the North-Western field. P40C is more abundant in North-Western and Northern coalfields than in the South Coast and South-Western fields. P2A and P40A reach maximum development in the Northern Coalfield—particularly between Newcastle and Swansea, where conditions of deposition were approximately central—and become less numerous in areas of marginal deposition. Type P3C is most abundant in marginal facies within the Ulan-Baerami, Western and South-Western Coalfields, is less numerous in the North-Western and South Coast fields, and reaches a minimum in the Northern Coalfield, where central conditions prevailed. Other types are more abundant in different fields which do not appear to be geographically related. Type P1A, for example, reaches 9·2 and 10·3 per cent. in the Northern and South-Western Coalfields, respectively, while in other areas it varies from 3 to 6 per cent.

Table 5 shows also several instances in the Newcastle Measures where spore-types are present in some coalfields and absent in others. This occurs with rarer types, and, in some cases, there is a possible relationship between absence of spores and palaeogeography. For example, five spore-types (P19A, P21A, P33A, P35A, P40A) are present in all areas except the South-Coast and North-Western Coalfields, which represent the southern and northern extremities of coal-measure deposition in the area at present under consideration. In another case, type P34C is present in all marginal areas of deposition, but absent where central conditions obtained in the Northern Coalfield.

Stratigraphical Distribution of Spore-Types.

Stratigraphical distribution of spore-types in Greta, Tomago and Newcastle Measures was studied by obtaining average relative percentages for types in all samples from each of the three measures. Results are given in Table 5 under the heading "Stratigraphical Distribution". Of the forty-eight different types, thirty-four occur in all measures, and the remaining fourteen types appear to have limited ranges.

Ranges and relative abundance of the fourteen limited types, together with examples of variation in abundance of types common to all measures, are illustrated in Fig. 3. Of the three rectangles opposite each spore-type in this diagram, the one completely filled-in represents the coal measures in which maximum development occurs. The other

TABLE 5.
Stratigraphical and Palaeogeographical Distribution of Microspores.

Spore-Types.	Stratigraphical Distribution.			Palaeogeographical Distribution.					
				Newcastle Measures: Different Coalfields.					
	Newcastle Measures. All Coalfields.	Tomago Measures. All Coalfields.	Greta Measures. All Coalfields.	Northern.	South Coast.	South-Western.	Western.	Ulan-Baerami.	North-Western.
P1A ..	6·4	6·3	2·4	9·2	5·7	10·3	4·2	3·1	6·0
P1B ..	6·0	8·3	11·9	5·8	10·6	6·4	5·8	4·0	3·5
P2A ..	2·2	1·6	0·7	4·5	1·6	1·4	1·6	3·3	0·9
P3A ..	11·3	11·5	13·8	11·1	13·3	12·7	9·0	11·4	10·7
P3B ..	1·1	0·9	A	1·0	0·8	1·2	1·4	1·1	1·4
P3C ..	13·8	8·5	12·5	8·5	13·0	14·9	15·1	17·3	14·0
P4A ..	0·5	0·6	0·5	0·8	0·1	0·3	0·4	1·2	0·3
P4B ..	0·9	0·6	1·7	0·6	1·8	0·2	1·5	0·6	0·6
P4C ..	1·3	1·5	1·6	1·2	0·6	1·6	1·3	1·3	1·7
P5A ..	5·5	3·1	3·6	3·7	5·7	7·8	5·6	5·4	5·2
P5B ..	3·2	2·3	2·7	2·9	4·3	4·5	2·8	2·4	2·3
P5C ..	10·1	6·5	9·5	4·3	10·4	9·5	10·9	10·7	14·9
P6A ..	1·1	1·9	3·0	1·2	A	1·1	1·0	1·4	1·7
P7A ..	1·1	2·3	1·2	1·0	0·8	0·4	1·2	1·9	1·1
P8A ..	5·6	6·1	4·2	7·3	3·4	2·9	6·8	6·4	6·7
P9A ..	0·2	0·6	A	0·3	A	A	0·5	0·3	A
P9B ..	0·9	0·2	0·6	0·5	0·4	0·1	2·1	2·1	0·3
P10A..	2·3	2·6	2·7	3·2	1·0	2·1	3·1	2·2	2·4
P10B..	5·3	7·1	4·7	6·8	5·6	3·4	5·7	3·2	6·9
P13A..	0·6	1·0	A	1·0	0·4	0·7	0·5	1·1	A
P14A..	3·6	2·5	2·8	1·8	6·5	2·1	4·5	2·9	3·7
P15A..	A	A	0·7	A	A	A	A	A	A
P16A..	1·1	2·9	0·1	1·0	0·6	1·3	0·8	1·1	2·0
P17A	1·1	2·0	0·3	1·2	1·0	1·8	0·6	0·8	1·4
P18A..	0·6	0·8	0·3	0·6	1·4	0·3	0·2	A	1·1
P19A..	0·3	1·0	0·1	0·8	A	0·3	0·1	0·5	A
P20A..	0·5	1·2	0·1	0·3	0·6	0·6	0·4	0·4	0·6
P21A..	0·3	A	A	0·2	A	0·7	0·2	0·6	A
P23A..	0·5	0·5	0·9	0·9	0·4	0·3	0·4	0·3	0·3
P23B..	0·4	0·4	0·3	0·4	0·8	0·9	0·1	A	0·3
P26A..	0·4	0·6	3·0	0·8	A	0·6	A	0·6	0·7
P28A..	0·1	A	1·9	0·3	A	0·1	A	A	A
P29A..	0·1	A	1·2	0·4	A	0·3	A	0·1	A
P29B..	1·3	0·1	5·2	1·5	1·8	1·7	1·5	1·0	A
P30A..	A	0·3	0·5	A	A	A	A	A	A
P32A..	A	A	1·0	A	A	A	A	A	A
P33A..	0·1	A	A	0·2	A	0·1	0·1	0·4	A
P33B..	0·5	1·8	A	0·4	1·2	0·5	0·6	0·3	A
P34A..	0·3	A	A	A	A	0·8	0·2	0·1	0·7
P34B..	0·8	0·7	0·8	0·1	0·8	1·1	1·2	0·6	1·1
P34C..	0·4	0·7	0·2	A	0·3	1·0	0·3	0·3	0·6
P35A..	0·2	1·4	0·4	0·3	A	0·3	0·4	0·1	A
P38A..	0·7	1·7	0·2	0·8	1·0	0·8	0·9	0·5	0·4
P40A..	0·8	0·7	A	2·5	A	0·9	0·5	0·6	A
P40B..	1·3	0·4	A	1·6	1·6	0·7	1·5	1·1	1·1
P40C..	3·1	3·7	1·0	5·6	1·3	2·8	2·0	2·7	4·1
P40D..	0·8	2·4	0·5	1·8	0·1	0·3	1·1	1·0	0·7
P41A..	1·2	1·1	2·3	1·9	0·7	0·5	1·8	1·5	1·1

two are filled-in according to the fractions of the maximum abundance their spore-percentages represent. For example, the Greta-Measures rectangle for P1B is completely filled-in, having a maximum abundance of 11·9%. The Newcastle-Measures rectangle for P2A is entirely filled-in, having a maximum abundance of 2·2%. In each case the remaining two rectangles are filled-in to fractions of 11·9% and 2·2% respectively. Where a spore-type is absent, the base of the rectangle is shown by a broken line.

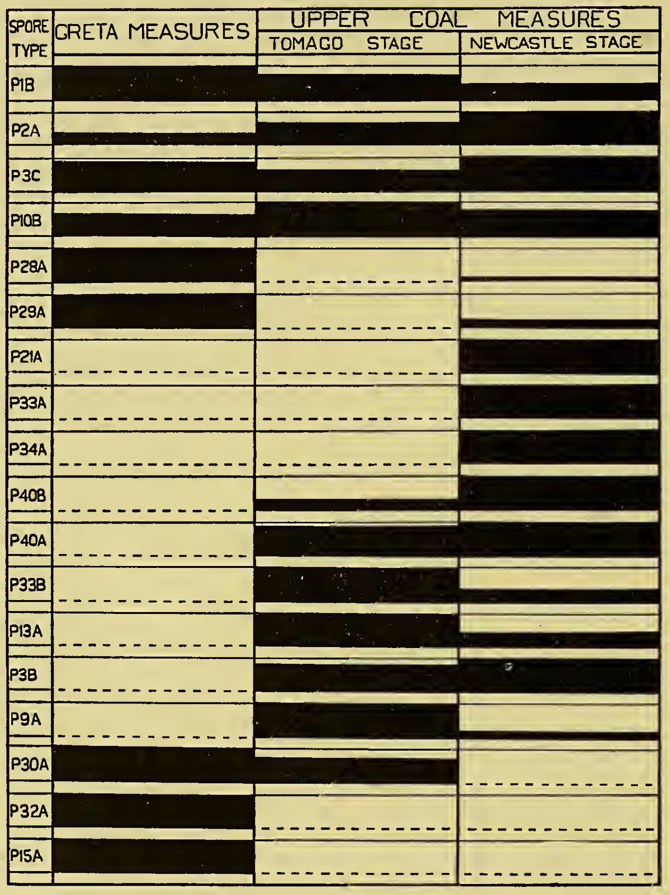

Fig. 3.—Stratigraphical distribution of certain microspore-types.

Four examples of variation in abundance of types common to all measures are illustrated at the top of the diagram. Type P1B has maximum development in Greta Measures, and minimum in the Newcastle Measures. On the other hand, P2A shows progressive increase in abundance from Greta to Newcastle Measures. Irregular trends are shown by other types such as P3C, which is more abundant in Greta and Newcastle Measures, and P10B, which reaches maximum development in Tomago coals.

Of the fourteen types with limited ranges, P32A and P15A have been found only in Greta Measures, and P30A has been identified in Greta and Tomago Seams, but not in the Newcastle Measures. Six types, P40B, P40A, P33B, P13A, P3B and P9A, occur in Tomago and Newcastle Measures, but have not been found in Greta-Measures. Three of these reach maximum development in the Newcastle Measures, and the other three in Tomago Measures. Three spore-types, P21A, P33A and P34A, have been recognized only in Newcastle Measures. Types P28A and P29A have been found in Greta and Newcastle coals, but not in Tomago coals.

The foregoing results must be confirmed or modified by subsequent work on large numbers of samples, but Fig. 3 suggests that certain types have limited ranges and it is possible that they may eventually be used as determinative fossils in correlating Permian strata. Caution is necessary, however, particularly in correlating widely separated occurrences which may have accumulated under different conditions of deposition, as a type may be absent from the marginal facies of a series and yet be present in central regions. Evidence of restricted palaeogeographical distribution of this nature was found in the Newcastle Measures, as already discussed.

Groups of Microspore-Types.

This section deals with relative abundance and distribution of microspores in terms of groups. The work was carried out as characteristic assemblages of groups may prove useful in stratigraphical correlation or the study of Permian floral assemblages.

Spore-types were divided into two series of seven groups: those which appeared to be morphologically related, and those which possessed similar forms of ornamentation. The first series (A to G), referred to as "Morphological Groups", bring together spores with similar fundamental features, such as nature of tetrad scar or dehiscence, body-shape and number of wings, irrespective of ornamentation. In the second series (1 to 7), referred to as "Ornamentation Groups", the spores are grouped on the basis of general forms of ornamentation and presence of wings, without respect to body-shape or dehiscence. The essential features of the seven groups in each series, and the spore-types allotted to each group, are shown in Table 6.

Table 6.
Grouping of Microspores.

Groups.		Character of Group.	Permian Spore-Types. (See Table 1.)
Morphological.	A	Tetrahedral; Trilete.	P—1A, 1B, 2A, 6A, 7A, 16A, 17A, 21A, 26A.
	B	Spheroidal; Trilete.	P—4A, 4B, 4C, 9A, 9B, 14A, 19A, 29A, 29B, 41A.
	C	Monowinged; Trilete.	P—32A, 34A, 34B, 34C.
	D	Spheroidal; Monolete.	P—5A, 5B, 5C, 10A, 10B, 15A, 20A, 30A.
	E	Ellipsoidal; Monolete.	P—3A, 3B, 3C, 8A, 13A, 18A, 23A, 23B, 28A.
	F	Monowinged; Monolete.	P—33A, 33B, 35A.
	G	Biwinged; Monolete.	P—38A, 40A, 40B, 40C, 40D.
Ornamentation.	1	Psilate.	P—1A, 1B, 2A, 3A, 3B, 3C, 4A, 4B, 4C, 5A, 5B, 5C, 41A.
	2	Granulate.	P—6A, 7A, 8A, 9A, 9B, 10A, 10B.
	3	Reticulate.	P—13A, 14A, 15A.
	4	Echinate.	P—16A, 17A, 18A, 19A, 20A.
	5	Striate.	P—21A, 23A, 23B.
	6	Verrucate.	P—26A, 28A, 29A, 29B, 30A.
	7	Winged.	P—32A, 33A, 33B, 34A, 34B, 34C, 35A, 38A. 40A, 40B, 40C, 40D.

Variations in abundance and distribution were investigated by obtaining averages for abundance of types belonging to different groups. In each spore-count the number of spores belonging to each group was expressed as a percentage of the total number identified. Averages were then obtained for the different groups in all samples from each of the coal measures and coalfields. Finally, averages were calculated for each group in the whole of the Permian. Results are given in Table 7.

TABLE 7.
Stratigraphical and Palaeogeographical Distribution of Microspore-Groups.

Spore-Groups.		Whole of Permian.	Stratigraphical Distribution.			Palaeogeographical Distribution.					
						Newcastle Measures: Separate Coalfields.					
			New-castle Measures All Coal-fields.	Tomago Measures Northern Coal-field.	Greta Measures Northern Coal-field.	South Coast.	South-Western.	Western.	Ulan-Baerami.	Northern	North Western.
Morphological.	A	22·5	19·6	25·5	22·5	20·2	23·3	15·5	16·7	24·9	17·1
	B	11·5	10·3	8·1	16·0	12·3	7·1	13·6	11·1	9·8	7·8
	C	1·6	1·4	1·4	2·0	1·1	2·2	1·7	0·9	A	2·4
	D	24·9	27·4	23·0	24·4	27·7	27·9	28·5	26·7	21·2	32·4
	E	32·5	34·1	29·6	33·7	33·6	34·0	33·4	38·0	31·1	34·4
	F	1·5	0·8	3·2	0·4	1·2	1·0	1·1	0·8	0·9	A
	G	5·8	6·7	9·1	1·7	4·0	5·6	6·0	5·9	12·4	6·3
Ornamentation.	1	60·0	64·2	52·7	63·0	69·0	71·2	61·2	65·6	55·4	62·5
	2	17·8	16·5	20·5	16·3	11·2	10·0	20·4	17·9	20·3	19·1
	3	3·7	4·2	3·5	3·5	6·9	2·8	5·0	4·0	2·8	3·7
	4	4·1	3·6	7·8	0·8	3·6	3·7	2·2	2·6	4·5	5·1
	5	1·0	1·2	0·8	1·1	1·3	1·9	0·8	0·8	1·5	0·7
	6	4·9	1·9	1·0	11·8	1·6	2·7	1·5	1·7	3·0	0·7
	7	9·5	8·9	13·7	6·0	6·4	8·6	8·8	7·6	13·4	8·6

RELATIVE ABUNDANCE OF MICROSPORES BELONGING TO DIFFERENT GROUPS.

Relative abundance of spores in the seven groups of each series in all coalfields and measures is illustrated in Fig. 4. Morphological and Ornamentation Groups are arranged in order of abundance from left to right. Vertical columns above group letters and numbers indicate relative average percentages for all types in each group.

The Morphological Groups show comparatively even gradation in relative abundance. Group E (ellipsoidal-monolete) representing 32·5 per cent. is followed by Group D (spheroidal-monolete), 24·9 per cent.; Group A (tetrahedral-trilete), 22·5 per cent.; and Group B (spheroidal-trilete), 11·5 per cent. The three remaining groups, including winged spores, have averages of less than 10 per cent. Of these, Group G (biwinged-monolete) is most common, while Group C (monowinged-trilete) and Group F (monowinged-monolete) are comparatively rare. In general, monolete spores are more numerous than trilete in both winged and non-winged groups.

The Ornamentation Groups show a decidedly uneven gradation in relative abundance. Psilate spores, Group 1, averaging 60 per cent., are three times more numerous than granulate types, Group 2, averaging 17·8 per cent. Winged spores, Group 7, are next with 9·5 per cent. These are followed by the verrucate, echinate and reticulate types, Groups 6, 4 and 3, respectively, averaging between 3 and 5 per cent. The least common are the striated spores, Group 5, averaging 1 per cent.

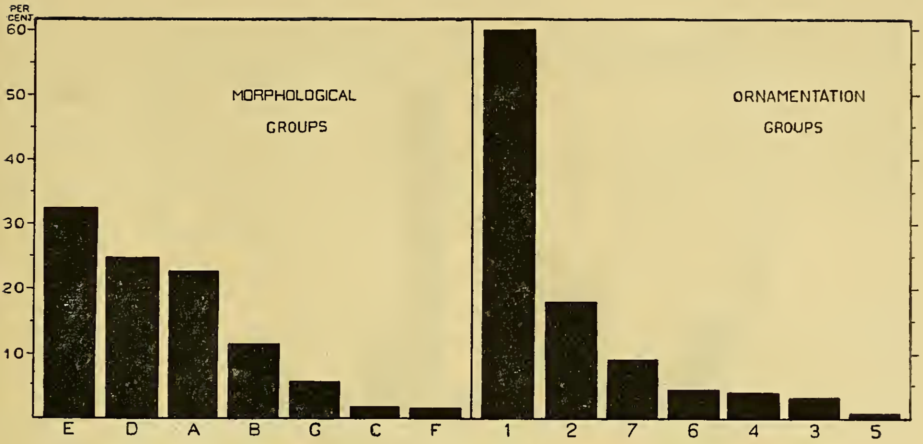

Fig. 4.—Relative abundance of microspores belonging to different groups.

Stratigraphical Distribution of Microspore-Groups.

Figures for average percentages given in Table 7 show variation in abundance for both series of groups throughout Greta, Tomago and Newcastle Measures. The results are illustrated graphically in Fig. 5. Vertical columns, proportional to percentages for each group, stand opposite different coal measures. The diagram illustrates stratigraphical variation for each group, and also assemblages for both series of groups in the three different coal measures.

The majority of Morphological Groups show very little stratigraphical variation, particularly the more abundant Groups, E, D and A. Of the less abundant groups, G and F attain maximum development in Tomago Measures, while Group C is most numerous in Newcastle Measures. The Ornamentation Groups show greater stratigraphical variation. The abundant psilate spores, Group 1, are more numerous in Greta and Newcastle Measures than in the Tomago. Echinate spores, Group 4, show a well-defined maximum in Tomago Measures. Verrucate types, Group 6, are more than five times as numerous in Greta as in other measures, and winged spores, Group 7, attain a definite maximum in Tomago Measures.

Fig. 5 may also be regarded as three pairs of small diagrams. Each pair opposite the different coal measures illustrates typical assemblages for Morphological and Ornamentation Groups. In Morphological Groups, the profiles of the three diagrams are similar in essential features. This means that the general assemblage for Morphological Groups is typical in all coal measures, and that the diagram for order of abundance in all measures (Fig. 4) is a characteristic and constant assemblage for the whole of the Permian. Assemblages for Ornamentation Groups are more variable. The profile of Groups 1, 2 and 3 is typical in all three coal measures, but important variations occur in Groups 4 to 7. For example, in Newcastle and Tomago Measures, Group 7 is four to thirteen times more abundant than Group 6, but in the Greta Measures, Group 6 is twice as numerous as Group 7. Similarly in the Tomago Measures, Group 4 is nine times more abundant than Group 5, but in the Greta Measures Group 5 is more numerous than Group 4.

The constant assemblage for Morphological Groups probably has important palaeobotanical implications, but the variable assemblage of Ornamentation Groups would appear to be the more promising in stratigraphical correlation—if certain features in assemblage can be established as characteristic of different coal measures. The higher proportion of verrucate spores, Group 6, in the Greta than in other measures appears to be a typical feature, as it persisted in all samples of Greta coal examined.

Palaeogeographical Distribution of Microspore-Groups in the Newcastle Measures.

Average percentages are shown in Table 7 for relative abundance of spore-types belonging to all groups in coal samples from the Newcastle Measures throughout different coalfields.

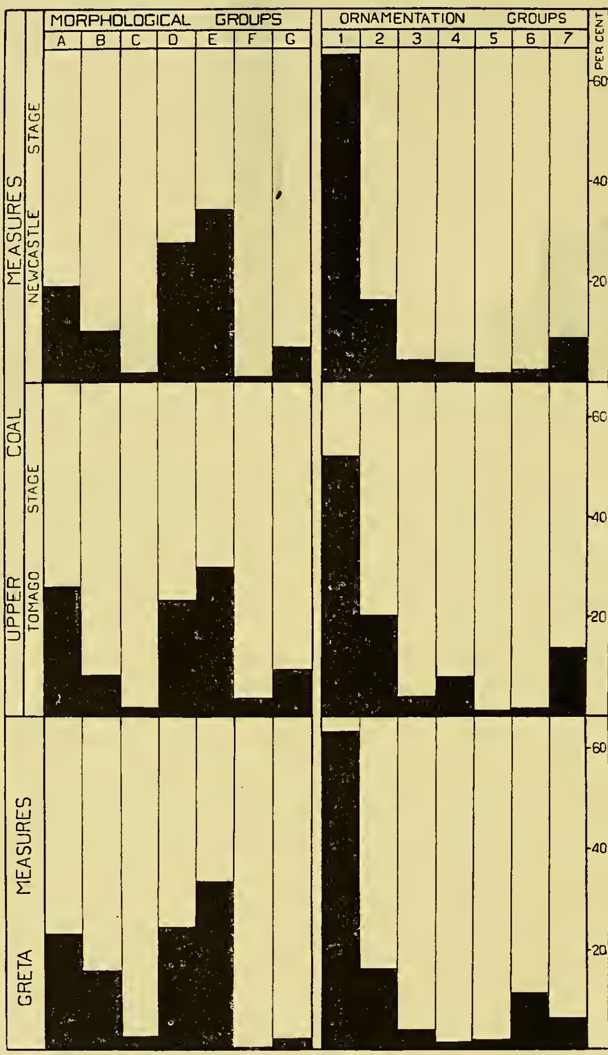

Fig. 5.—Stratigraphical variation in assemblages of microspores belonging to different groups.

Biwinged-monolete spores belonging to Morphological Group G and winged spores of Ornamentation Group 7 are considerably more numerous in the Northern Coalfield than in marginal areas of deposition. All Ornamentation Groups are represented in every coalfield. In the Morphological Groups, the monowinged-trilete spores, Group C, have not been found in the Northern Coalfield, and monowinged-monolete types, Group F, appear to be absent from the North-Western Coalfield.

Apart from the foregoing examples, there is no reliable evidence of definite trends or relations to palaeogeography, although the majority of groups show what appear to be small random variations in abundance from one coalfield to another.

Summary.

Forty-seven representative seam-samples from all measures and fields in the main Permian basin were examined. Microspores were found abundantly in all coals, except those from the South-Coast Coalfield. No variation of special significance is revealed in diversity of types present in different coals. Most abundant spores are all simple forms,

including the smallest of New South Wales Permian types. Lateral variation in abundance of some spore-types in the Newcastle Measures is related to palaeogeography. Of the forty-eight spore-types, thirty-four occur in all measures, and fourteen appear to have limited ranges.

Relative abundance and distribution of spores is considered in terms of morphologically-related groups, and groups with similar forms of ornamentation. Morphological Groups show a typical assemblage in all coal measures, while assemblages for Ornamentation Groups are more variable. Lateral variation in group-assemblages does not appear to be related to palaeogeography.

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